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Economic Evaluation of Agricultural Research

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ECONOMIC EVALUATION OF AGRICULTURAL RESEARCH

Purpose of this Report

This report identifies several key issues addressed in past economic evaluations of agricultural research and summarizes the general findings of these evaluations. In identifying and summarizing, it draws on several published studies which have reported on both (1) alternative methods for research evaluations and (2) empirical estimates of the economic benefits accruing to research. The report does not undertake to evaluate specific methods or the results of individual studies, but its purpose is to provide a summary of key generalizations which can be drawn from past work.

Why Do Research Evaluation?

Aside from the motives of intellectual curiosity and methods development, there are three broad purposes for research evaluation. The first is to assist in the effective planning of future research (both at the project and program levels). The second is to estimate research payoff for the purpose of justifying financial support for future research. The third is to help guide the development of effective research and technology policies. It is easy to conclude that the focus of research evaluation for the above listed purposes should be mainly forward looking (ex ante). But evaluation of past research is often the major source of information available for planning future work. Thus, ex post evaluations of past research (both formal and informal) can serve as important inputs into planning future research. But seldom, if ever, should these evaluations serve as the sole basis for future planning. No future situation is identical to the past, and decisions about future research priorities involve a number of considerations in addition to expected economic payoff. Moreover, new research areas become important for which there is often no past history to evaluate.

Procedures of Economic Research Evaluation

A sizable list of methods has been developed for economic evaluation of agricultural research. And, any specific evaluation effort can adhere to the procedures of one or more of these methods. But from a more general perspective, evaluations fall into the following three broad categories:

(1) The use of research investments (expenditures) as one of several arguments, along with such traditional inputs as land, labor, and purchased inputs, in the estimation of production functions which have the value of agricultural output (or some similar measure) as the dependent variable. From such production functions, one can compute such measures as benefit/cost ratios, rates-of-return, and average and marginal products for research investments. This permits evaluation of the consequences on output of changing the level of research expenditures.

(2) The use of procedures which permit estimation of the shifts in supply (typically for individual commodities or commodity groups) which can be attributed to research investments. From such supply curve shifts, one can compute such measures as producer and consumer benefits (in the form of economic surplus resulting from the research), benefit/cost ratios, value of inputs saved, and rates-of-return on research investment. An advantage of the economic surplus approach is that it permits evaluation of the distribution of economic gains among various beneficiary groups.

(3) The use of informed judgment, including scoring models, delphi procedures, etc., to project expected benefits from alternative research efforts. It is likely that procedures of this "informed judgment" type will continue to play a key role in support of research prioritization and planning. Given the increased importance of considering such externalities as environmental quality, food safety, and rural economic and social structure, future priority setting will not be based solely on results stemming from analyses based narrowly on projected changes in economic efficiency. Granting this, selective ex post and ex ante analyses of a more formal type can be used in support of judgments about future research strategies.

Each of the above procedures can be augmented by additional information gained via rather simple procedures of observation and logic. For example, experience has shown that some types of research are more productive than others. And some are more consistent than others with current and future research priorities. In summary, the crucial elements of more formal research evaluation procedures are credible estimates of research inputs and outputs (preferrably including externalities) and a reasonable logic for relating the two in cause-effect dependency.

In the sections which follow, we provide brief discussions of each of several important topics related to the role of public and private investments in agricultural research.

I. Agricultural Research as a Long-Term Investment

Agricultural research has far-reaching consequences on economic efficiency and profitability in farming; factor productivity and use; quantity, quality, and price of agricultural and food products; environmental quality; and foreign exchange earning from agricultural exports. In addition, it has been largely responsible for the release of farm labor and other resources from agriculture to other sectors of society, and expanded aggregate economic activity linked to increases in agricultural production. Hence, agricultural research can be viewed as a long-term investment in improving society's well-being.

New ideas and innovative technologies which will result from current agricultural research activities may influence the food and agricultural sectors for many years to come. There are several lags which explain why many of the benefits will be forthcoming long after the initial research activity.[1] First, there is a lag involved in the search for new knowledge. Research results leading to new ideas and technologies become available only after some time has elapsed after the initial investment in research. There is a second lag related to adoption which occurs between the time a new technology is developed and the time it is actually applied. Often only a few producers may adopt the new technology initially but, if it proves successful, then others also adopt. Increased investment in extension activities aimed at informing producers about the technology would be expected to reduce the length of this adoption lag. A third lag relates to the aggregate impact of new technology on productivity. When only a few innovative producers use the technology, it first has only a small impact on productivity. But as more and more producers adopt the technology its impact on productivity and its benefits to society become larger and larger through time. However, many technologies are used only for a limited period of time. Their effectiveness may be eroded away by insects and diseases and/or they may become obsolete as new technologies replace them or the changing economic environment reduces the profitability associated with using them. Hence, special recognition needs to be given to the dynamic nature of direct and indirect benefits of agricultural research to farmers, farm workers, rural residents, consumers, and

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[1]Evenson, Robert, "The Contribution of Agricultural Research to Production," Journal of Farm Economics 49(1967): 1415-25.

society in general.[2] Recent studies report that very long lags of even 30 years or more may be necessary to capture all of the impact of some research on agricultural output.[3]

Since many of the benefits from agricultural research accrue over a long period, failure to adequately support research currently will mean lower benefits later. Sustained long-term support of agricultural research is needed in order to maintain an efficient, effective agricultural research system.[4] For example, facility construction and use, employment of scientists, and project planning and conduct cannot be turned off and on in response to short-term needs. Each dollar of underfunding relative to the economically efficient level of research and extension expenditures has been estimated to (a) cost the government more than $2.50 if it later makes up for the low investment level or (b) cost consumers almost $4.50 if the government does not make up for the low level of investment.[5] However, the variability of funding for agricultural research has intensified through effects of inflation, economic stagnation, uncertain appropriations, inconsistent goals, political abuse, and inattention.[6] Anticipated funding, which is a consistent, sustained level of funding aimed at long-term goals, is much more effective in increasing agricultural productivity than unanticipated funding which is variable from year to year.[7]

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[2]Rausser, Gordon C., Alain de Janvry, Andrew Schmitz, and David Zilberman, "Principal Issues in the Evaluation of Public Research in Agriculture." Presented at symposium on Methodology for Evaluation of Agricultural Research, Minneapolis, Minnesota, May 12-13, 1980.

[3]Pardey, Philip G. and Barbara Craig, "Causal Relations Between Public Sector Agricultural Research Expenditures and Output," American Journal of Agricultural Economics 71(1989): 9-19.

[4]Knutson, Marlys and Luther G. Tweeten, "Toward An Optimal Rate of Growth in Agricultural Production Research and Extension," American Journal of Agricultural Economics 61(1979): 58-63.

[5]White, Fred C. and Joseph Havlicek, Jr., "Optimal Expenditures for Agricultural Research and Extension: Implications of Underfunding," American Journal of Agricultural Economics 64(1982): 47-55.

[6]Bonnen, James T, "A Century of Science in Agriculture: Lessons for Science Policy," American Journal of Agricultural Economics 68(1986): 1065-80.

[7]Langston, Jackie B. and Fred C. White, Measuring the Impact of Fluctuations in Research Funding, Faculty Series FS89-67, University of Georgia, Division of Agricultural Economics, December 1989.

II. Economic Returns to Research Investments

Beginning with the initial work of Griliches[8] in 1958 to estimate the rate of return to public investments for research on hybrid corn, a large number of studies have shown the economic payoff for agricultural research to be high and indicative of an underfunding of agricultural research.[9] And, these returns are high for both science-oriented and technology-oriented (applied) research. An updated summary of specific rate of return estimates for public research investments made over the past 15 years is shown in Table 1 and indicates annual internal rates of return on research investments ranging from a low of 22 percent to a high of 202 percent. Moreover, other measures of economic returns, including benefit/cost ratios and the marginal value products from agricultural research investments, also continue to be high. For example, recent analysis conducted by Ansoanuur[10] for the fresh-winter-tomato industry shows the marginal product from the last dollar of research investment to be about $10.85 for preharvest and $12.70 for postharvest research and development. Araji estimates the marginal product of wheat research in the Western Region to be $39.70.[11]

Other recent analysis by Araji[12] provides initial insight into the returns for agricultural research by functional research categories [(a) maintenance, (b) short-run applied, and (c) long-run] at the Idaho Experiment Station. Results indicate impressive returns to all three categories with the highest annual rate of return on investment (62 percent) coming from maintenance research, the objective of which is to prevent a decline in productivity gains already achieved by previous R&D. These results are consistent with an expected need to invest more heavily in maintenance research as productivity gains, particularly for crops, push per unit yields to higher and higher levels.

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[8]Griliches, Zvi, "Research Costs and Social Returns: Hybrid Corn and Related Innovation," Journal of Political Economics 66(1958): 419-31.

[9]"Public Research in Agriculture, Forestry and Home Economics: Its Role, Its Benefits and Selected Issues," IR-6 Information Report No. 87-3, Department of Agricultural and Applied Economics, University of Minnesota, November 1987.

[10]Ansoanuur, James S., "Evaluating Return to Postharvest Research and Development in the Fresh-winter-tomato Industry," Unpublished Ph.D. Dissertation, University of Florida, 1988.

[11]Araji, A.A., "Return to Public Investment in Wheat Research in the Western United States," Canadian Journal of Agricultural Economics 37(1989):467-479.

[12]Araji, A.A., "Return to Investments in the Idaho Agricultural Experiment Station by Functions," Research Bulletin No. 144, Agricultural Experiment Station, University of Idaho, October 1988.

Unfortunately it is much more difficult to quantify the economic returns to research which does not result in the production of marketable commodities. Research on soil conservation, water quality and rural community development are examples of the latter. This problem is not, however, unique to agricultural research. The economic impacts of much other public sector research and other public programs are equally difficult to evaluate. Of critical importance in assessing the impacts of noncommodity research is a clear ex ante specification of research objectives, the expected payoffs from these types of research, and a post-research evaluation of the degree to which research objectives have been achieved. Such evaluations can perhaps be best achieved via a multistage "technology assessment" type of approach.

Table 1. Summary of Rate-of-return Estimates for Agricultural Research Investments for the Period 1974 to Present (U.S. only)

Study	Commodity	Time Period	Annual Internal Rate of Return
White, Havlicek, and Otto, 1979	Aggregate	1958-77	42*
Norton, 1981	Cash grains	1974**	44 - 85
	Dairy	1974**	33 - 62
	Livestock	1974**	66 - 132
Smith, Norton, and Havlicek, 1983	Cash grains	1978**	202
	Dairy	1978**	25
	Poultry	1978**	61
	Livestock	1978**	22
White and Havlicek, 1982	Aggregate U.S.	1977-81	48
	by region	1977-81	23 - 74
Braha and Tweeten, 1986	Aggregate U.S.	1959-82	47*
Araji, 1989	Wheat, western region	1951-85	50
	Wheat, western region (varietal improvement research only)	1951-85	97
Ortiz and Norton, 1990	Aggregate U.S.	1987**	31

*Research and extension, combined.

**Indicates census year for which agricultural output and conventional inputs were measured. Research expenditures are lagged by appropriate periods.

III. The Distribution of Research Benefits

Historically, the benefits of publicly funded agricultural research have flowed not only to producers of agricultural products, but also to consumers and agribusiness firms. And, in the case of commodities which are exported, some of the benefits flow to foreign consumers as well. Moreover, some benefits also flow to foreign producers from research results which are transferable across country borders.

A number of factors affect the manner in which research benefits are distributed between producers, consumers, and agribusiness firms. The greater the consumer price response (elasticity of demand) for the farm commodity involved, the more likely that producers will benefit from the research. And, the more inelastic the demand, the more likely producers will not benefit and may even lose economically following technical change. Also, if the producer price response (supply elasticity) is absolutely greater than the demand elasticity, consumers will tend to receive a larger share of the benefits than producers. Since the demand for most farm products is highly inelastic, particularly in domestic markets, producers have difficulty in retaining a major portion of the economic benefits of research unless: (1) consumer demand shifts in response to new or improved products and/or (2) there is an expansion in the volume of commodity sales in more demand elastic export markets.

U.S. consumers have benefited greatly from research via cheaper food and increased consumer choice. Recent work by Ansoanuur on the returns to R&D in the fresh-winter-tomato industry[13] indicates that about one-third of the research benefits accrue at the grower level and two-thirds to consumers. This is the approximate distribution of benefits for both preharvest and postharvest research. Recent analysis by White[14] indicates that the average benefit-cost ratio to consumer family units for their tax-based investment in agricultural research is about 2.7 to 1.

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[13]Ansoanuur, James S., "Evaluating Return to Postharvest Research and Development in the Fresh-winter-tomato Industry," Unpublished Ph.D. Dissertation, University of Florida, 1988.

[14]White, Fred C., "The Benefits and Costs to U.S. Consumers in Various Income Categories of Investment in Agricultural Research," IR-6 Information Report No. 87-1, Georgia Agricultural Experiment Station, Athens, Georgia, June 1987.

Similar reasoning as that above for producers and consumers applies to the allocation of research benefits among producers and input suppliers. Since producer demand response has been high for many improved technical inputs (such as chemicals, improved seed varieties, etc.), agribusiness suppliers of these inputs have profited from expanded marketings. But the suppliers of inputs made obsolete by new technology are disadvantaged unless they can share in the market for new improved inputs.

As a general rule, research benefits have accrued to producers somewhat in proportion to size of farm. This is particularly true for most mechanical, biological, and chemical research which produces benefits somewhat in proportion to crop acreage produced or size of livestock enterprise. Low income consumers, on the other hand, have benefited proportionately more than high income consumers since lower income family units spend a higher proportion of their income for food and are taxed (to support agricultural research) at a proportionately lower rate.

IV. Spillover Effects

The results of agricultural research frequently spill over the border of the state or country conducting the research. A wheat variety developed in one state may be grown in several states, or a new livestock vaccine may be used in several countries. These spillovers influence production and prices in recipient states or countries. In fact, even if the knowledge or technologies themselves do not spill over, price effects may spill over due to the effects of additional (research-induced) production on product prices.

Differences in human, natural, and physical resource bases influence the extent to which new technologies move across geographic areas. Relatively basic research is often less geographically specific and, thus, more likely to be transferred than relatively applied research. Because of this ease of transfer and the fact that a high proportion of the benefits of basic research cannot be captured by the state (or country) conducting the research, state governments have an incentive to underinvest in basic research. This tendency for underinvestment in basic research strengthens the argument for federal support to state agricultural experiment stations and for multilateral support of research at international agricultural research centers.

Empirical evidence suggests that technology and price spillovers of agricultural research are substantial among states and that the spillovers differ, not only by types of research but by commodity and region as well.[15] The results of livestock research tends to spread more quickly and farther than results of crops research because the former is less dependent on geoclimatic factors. Within livestock, the results of poultry research spread more rapidly than that for cattle and swine. Spillover patterns differ substantially among crops as well. Soybeans, for example, are photoperiod sensitive, resulting in greater east-west than north-south spread of new varieties. Corn varieties, on the other hand, spread across the United States in more of an inverted U pattern following the number of heat units available.

The ratio of the benefits of all agricultural research accruing to the regions where the research occurred to the benefits of research which spilled over to other regions is illustrated in Table 2. In every region more benefits of research are realized outside the region where the research occurs than inside. In the Lake States, Corn Belt, Delta States, and Southern Plains, more than twice as many benefits spill over to other regions compared to the benefits staying within the regions. These spillovers provide a strong case for federal support to state and regional research.

The international environment for technology transfer is influenced by the presence of the International Agricultural Research Center (IARCS) supported by governments and foundations through the Consultative Group for International Agricultural Research. Although the purpose of the IARCS is to support agricultural research of use to developing countries, some research results also flow back to developed countries. Furthermore, price effects can spill over to developed from developing countries as new technologies increase production in the latter. In many cases, the income growth stimulated by increases in agricultural productivity in developing countries has resulted in increased demand for agricultural exports from developed countries.

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[15]Evenson, Robert E., Paul E. Waggoner, and Vernon W. Ruttan, "Economic Benefits from Research: An Example from Agriculture," Science 205(September 14, 1979): 1101-1107; Fox, Glenn, Robert E. Evenson, and Vernon W. Ruttan, "Balancing Basic and Applied Research: The Case of Agricultural Research," Bioscience (July/August 1987): 507-509; White, Fred C. and Joseph Havlicek, Jr., "Interregional Spillovers of Agricultural Research Results and Intergovernmental Finance: Some Preliminary Results," Evaluation of Agricultural Research, Minnesota Agricultural Experiment Station, Miscellaneous Bulletin No. 8 (1981): 60-70.

Not all research spillovers stem from public research. Some are the result of research by multinational firms, particularly in the chemical and machinery areas. In the last 10 to 15 years, multinational firms have increased their seed transfers across borders as well.

Table 2. Ratio of Research Spillovers to Regional Benefits from Research

Region	Ratio
Northeast	1.31
Lake States	2.73
Corn Belt	2.04
Northern Plains	1.40
Appalachia	1.19
Southeast	1.40
Delta	2.48
Southern Plains	2.80
Mountain	1.60
Pacific	1.89
Aggregate	1.73

Source: White, Fred C. and Joseph Havlicek, Jr. "Interregional Spillovers of Agricultural Research Results and Intergovernmental Finance: Some Preliminary Results." In Evaluation of Agricultural Research, Minnesota Agricultural Experiment Station, Miscellaneous Bulletin No. 8 (1981): 69-70.

V. Private Sector Research Issues

Research on the role of the private sector in agricultural research and development (R&D) has only recently been initiated. Several of the specific questions being asked in this research are listed below together with a brief discussion of their implications.

1. *Is the private sector doing enough R&D to keep productivity growing in the food and agricultural sector in order to keep the U.S. competitive in international markets?*

Private sector research on food and agriculture makes up about 60 percent of total food and agricultural research in the United States. The total public and private R&D expenditure is more than for any other country for which data on private sector research are available. Relative to the size of the agricultural sector (measured as value of agricultural output), the U.S. invests about 2.5 percent compared to 2.2 percent for France, 1.8 percent for Thailand, and 1.7 percent for Australia (Figure 1). A worrying fact, however, is that after 30 years of continuous growth in private research, which compensated in part for the slowdown in public research expenditures, real private R&D declined for the first time between 1986 and 1987, the last year for which data is available (Figure 2). The decline was sufficiently large to pull down the total U.S. expenditure on food and agricultural R&D. Since we do not know what the optimal level of private sector research is, we can not yet answer the question of whether or not there is enough.

2. *Is the private sector allocation of research resources optimal for society or is it biased away from what is socially optimal?*

The largest share of private food and agricultural research (about 25 percent) is on pesticides. About 12 percent is spent on agricultural machinery research.[16] These R&D shares may not be socially optimal because the patent system gives the inventor of new chemicals and machinery greater protection from competition than the inventor of a new plant variety. In addition, since companies that invent new chemicals usually do not have to pay for the negative externalities involved in their use, they have not considered those costs in their estimates of rates of return to research and, thus, may have overinvested in some kinds of research from society's perspective. Similarly, basing research investments solely on profit expectations can be expected to result in underinvestment in other important areas of research.

3. *Does private financing of public research bias public research?*

In a period of stagnant or declining government budget allocations for agricultural research, many research administrators have been aggressively seeking private research dollars to fund public

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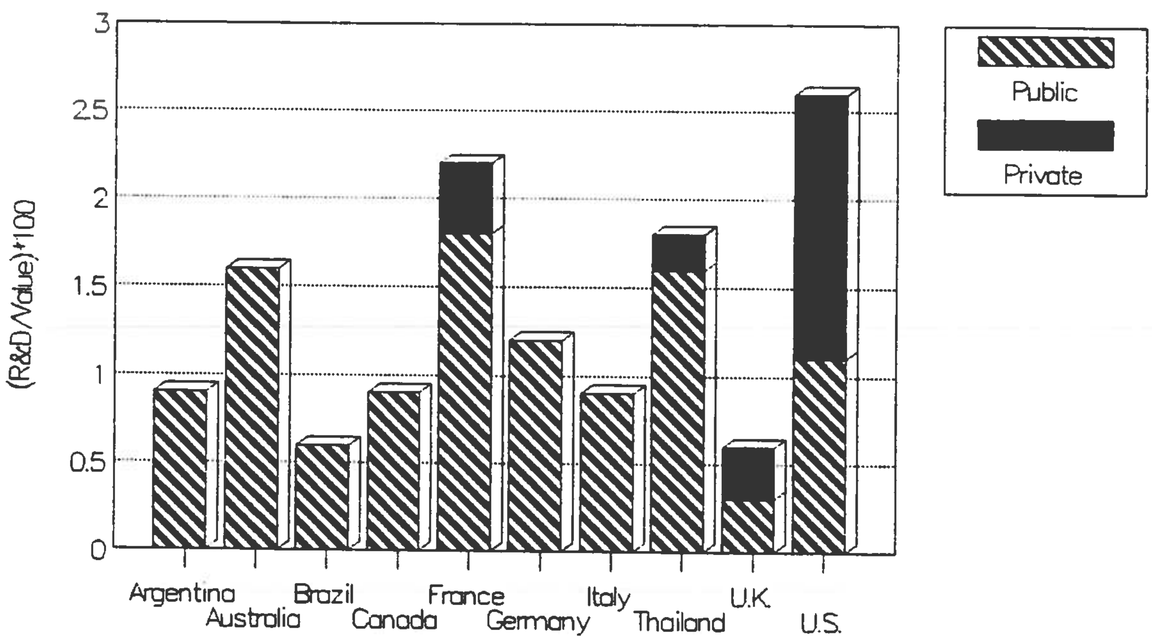
[16]Pray, Carl E. and Catherine Neumeyer, "Impact of Technology Policy on Research in the Agricultural Input Industries," Paper presented at the American Agricultural Economics Association Annual Meeting, Baton Rouge, Louisiana, 1989a.

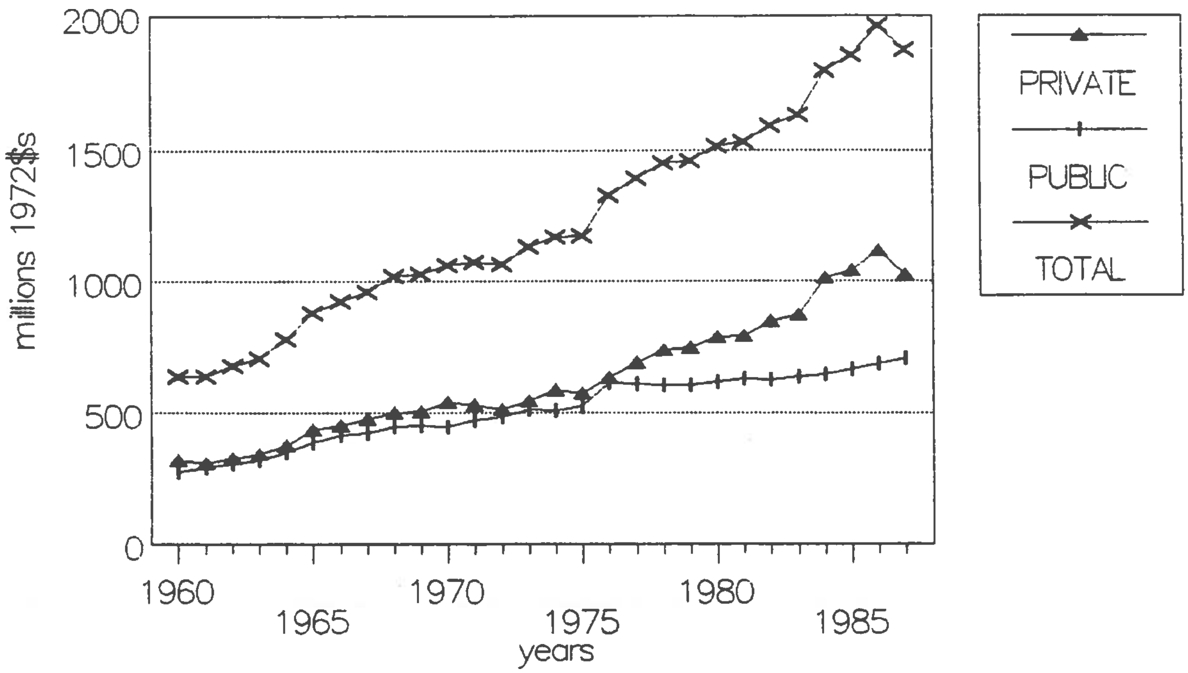
Figure 1: Food & Agriculture R&D as % of Value of Agricultural Production, 1985



Source: Carl E. Pray and Catherine Neumeyer. "Trends and Composition of Private Food and Agricultural R&D in the United States," forthcoming in Agribusiness: An International Journal, Summer 1990.

Data on private sector research are available only for France, Thailand, U.K. and the U.S.

Figure 2. Trends in Total U.S. Food and Agriculture R&D



Source: 1960-1980: Carl E. Pray and Catherine Neumeyer. "Trends and Composition of Private Food and Agriculture R&D Expenditure in the United States," Rutgers University, Dept. of Agriculture Economics and Marketing, P-02221-1-89, February 1989.

1987: Unpublished data from National Agricultural Chemicals Association, Pharmaceutical Manufacturers Association and National Science Foundation.

sector research. Yet little study has been made on the extent to which private funding may encourage public research in directions which are not socially optimal. For example, Canadian researchers have found that industry support for public research on malting barley resulted in increased emphasis on quality improvements and reduced emphasis on yield increases.[17] Quality improvements are of particular benefit to maltsters and brewers and yield increases to farmers. Yet farmer growers have also realized price gains via improvements in barley quality. And recent research at the University of Minnesota suggests that yield and quality improvements for malting barley can be complementary rather than competitive in research goals.[18]

Credible evaluation of possible bias of public research away from that which is socially optimal generally needs to be targeted to specific areas of agricultural research. A second need is to articulate a specification of research goals from a societal viewpoint. Without such specification it is difficult, if not impossible, to measure the extent of possible bias.

4. *Can the public sector influence the levels and priorities of private sector research?*

Recent research suggests that one of the most effective ways the public sector can stimulate private research is through public research.[19] Public sector research investment does stimulate increased private research in related areas. Other policy instruments that have been tried in recent years, such as the R&D tax credits and strengthened property rights, were not found to be statistically related to private R&D expenditures, although anecdotal evidence does suggest that private biotechnology research has been stimulated by patents and tax credits. The one policy besides public research expenditures that is statistically related to private R&D expenditures is regulation which has a negative impact on agricultural chemical research.

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[17]Ulrich, A., H. Furtan, and A. Schmitz, "Public and Private Returns from Joint Venture Research:
An Example from Agriculture," The Quarterly Journal of Economics, February 1986.

[18]For example, a malting barley variety scheduled for release by the Minnesota Agricultural Experiment Station in 1990 (M-52) has both quality and yield advantages over existing varieties.

[19]Pray, Carl E. and Catherine Neumeyer, "Trends and Composition of Private Food and Agricultural R&D Expenditure in the United States," Research Paper P-0221-1-89, Department of Agricultural Economics, Rutgers University, New Brunswick, New Jersey, 1989b.

These findings imply that greater investment in specific types of public research stimulates aggregate R&D in the same general areas by some multiplier and that public research in high priority areas can influence the direction of private research as well. This suggests that common policy at present--reducing public R&D when the private sector invests in an area of research--is too simplistic and should be reevaluated and probably revised.

VI. Effects of Public Policies on Research Benefits

This, too, is an area in which extensive research analysis has only recently been undertaken. Thus, the discussion which follows is intended to introduce the topic and not to provide recommendations based on extensive research results.

The benefits of agricultural research across commodities tend to be positively related to the total value of production. But what if, for example, that value of production has been influenced by price support policies? The benefits from research may be reduced by such policies. Alston, Edwards, and Freebairn recently analyzed the economic welfare implications of research-induced shifts in the supply curve in the presence of government policies.[20] They argue that significant biases are introduced into the measured welfare effects of research if a competitive equilibrium is assumed and policies which distort prices are ignored. The implication is that the competitive assumption overestimates the benefits of research. They conclude that "...policies also may have induced a relative overinvestment in research in highly protected industries." Other economists arrive at similar conclusions.[21]

The reason for the potential overvaluation of research benefits is that part of the increased commodity supply may be produced by resources bid away from other sectors by the price support policy. As a result, the value of the resources used in the supported commodity are artificially inflated by the price support policy. In most cases, those price supports are paid for by taxes.

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[20]Alston, Julian M., Geoff W. Edwards, and John W. Freebairn, "Markets Distortions and Benefits from Research," American Journal of Agricultural Economics 70(1988): 281-88.

[21]Lichtenberg, Erik and David Zilberman, "The Welfare Economics of Price Supports in U.S. Agriculture," American Economic Review 76(1986): 1135-41; Oehmke, James F, "The Calculation of Returns to Research in Distorted Markets," Staff Paper No. 87-106, Department of Agricultural Economics, Michigan State University, October 1987; and Oehmke, James F., "A Multiple Objective Explanation of Government Research and Target Price Policy," Staff Paper No. 88-5, Department of Agricultural Economics, Michigan State University, January 1988.

de Gorter and Norton[22] point out, however, that while the price support policies themselves can create social costs, the marginal benefits of research in the presence of those policies may not be seriously inflated. The reason is that governments have mechanisms in place, often employing a combination of policies to reduce income transfers in the face of supply shifts. For the U.S. crop sector, governments use a target price with acreage limitations and idled acreage, program yields, voluntary participation, and several other features that limit the quantity of deficiency payments. In the dairy sector, supported prices for milk automatically decrease after government support surpluses exceed a prespecified quantity. For example, Kaiser and Tauer estimate that the U.S. milk price support level would decrease by up to 40 percent in the 1990s if bovine growth hormone reduces the marginal cost of milk production as expected.[23]

For most crops, because (1) participation in farm programs is voluntary and a significant portion of total output is produced "outside" the programs, (2) payments are received by farms on program yields only, which are sometimes below actual profit-maximizing yields at market prices, and (3) participating farmers are limited by their "base" acreage which limits the acreage upon which payments are made, additional output generated as a result of research-induced supply shifts is likely to be valued close to its social value in most cases. While simple unrestricted price supports would clearly reduce the social value of research, actual price support policies with their countervailing components may influence the value of research only slightly. For example, de Gorter and Norton estimate that U.S. wheat policies reduce the benefits from research by only about 7 percent.

VII. Maintenance Research

Many types of agricultural research output depreciate in value over time. For example, new plant varieties frequently perform well for several years, but eventually yield less as insects or diseases evolve and attack them. Or, agricultural policies which derived from research conducted for a certain set of technological and price relationships do not serve well under new technologies and/or different

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[22]deGorter, Harry and George Norton, "The Critical Appraisal of Analyzing Gains from Research with Market Distortion." Unpublished paper, Department of Agricultural Economics, Cornell University, 1989.

[23]Kaiser, Henry and Loren Tauer, "Potential Impacts of Bovine Somatotropin on the U.S. Dairy Sector," Working Paper, Department of Agricultural Economics, Cornell University, 1988.

prices. The result of research depreciation is that a certain proportion of new research must be continually devoted to maintaining productivity, economic efficiency, or other gains realized from past research. This type of research is frequently called maintenance research. Failure to recognize the importance of maintenance research can result in an undervaluation of those types of research for which maintenance is a large component. Plant breeding for insect or disease resistance is an example.

Depreciation is more important in explaining research benefits in agriculture than in other industries. The biological character of agricultural production and the focus of agricultural research on improving productivity in biological production systems are the major causes of depreciation. Many agricultural research activities are directed towards developing direct suppressants of plant and animal pests via insecticides, herbicides, cultural practices, etc. Others emphasize breeding and selecting for crop and animal traits that provide resistance to the pests that are most prevalent and damaging under current field conditions. However, the composition of pest populations is neither constant nor passive to the environment. Farmer adoption of direct suppressants of current pests and of crops and animals having resistance to existing dominant classes of pests alters the environment in which these pests live. Natural selection then comes into play. Those pests which were formerly prevalent recede in numbers. Successor generations will be dominated by those which can survive, or even thrive, in the new environment created by the introduction of practices designed to control earlier pest generations. The result is that the initial positive productivity effects of introducing such practices, inputs, and genetic strains can decay over time.

Until recently, few studies had attempted to quantify the importance of maintenance research although there were numerous documented cases where research has depreciated and then been replaced by new research-based technologies. For example, a new strain of southern corn leaf blight caused a 15 percent drop in U.S. corn yields in 1970. Researchers developed new hybrids resistant to the blight. A recent article by Plucknett and Smith details several other examples.[24]

Recent economic analyses have provided some quantitative evidence of the importance of maintenance research. Heim and Blakeslee (1986) estimated that up to 70 percent of current research

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[24]Plucknett, D.L. and N.J. Smith, "Sustaining Agricultural Yields," Bioscience 36(January 1986): 40-45.

expenditures on wheat production in Washington State are needed to maintain current yields.[25] Blakeslee (1987) estimated that almost 90 percent of recent agricultural research and extension expenditures in the United States are needed to maintain productivity.[26] The latter number is high compared to estimates by Adusei and Norton (1989) and by Huffman and Evenson (1989).[27] Based on a survey of 2,400 agricultural scientists in the U.S., Adusei and Norton estimated that maintenance research represents slightly over one-third of the agricultural research aimed at producing biological technologies (Table 3). Huffman and Evenson examined CRIS funding data by Research Problem Areas (RPAS) and arrived at similar estimates (Table 3). While the exact numbers differ between studies, it is clear that a sizable portion of the agricultural research budget is needed for maintenance. Furthermore, the importance of maintenance research varies by the type of research and by commodity (Table 3).

In summary, available evidence suggests that under recent conditions, the presence of biological decay, coupled with major productivity advances due to past research and extension expenditures, has produced a situation where the level of expenditure needed to maintain productivity on a continuing basis is high. Thus, significant reductions in some areas of research support would not merely halt productivity growth; actual declines in productivity would occur. Furthermore, the need for maintenance research has probably increased over time as technologies have become more complex. As noted earlier,

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[25]Heim, M.N. and L. Blakeslee, "Biological Adaptation and Research Impacts on Wheat Yields in Washington," Department of Agricultural Economics, Washington State University, 1986 (mimeo).

[26]Blakeslee, L., "Measuring the Requirements and Benefits of Agricultural Maintenance Research." Paper presented at the symposium Evaluating Agricultural Research and Productivity, Atlanta, Georgia,
January 29-30, 1987.

[27]Adusei, E. and G.W. Norton, "The Magnitude of Maintenance Research in the United States," Journal of Production Agriculture, October-December, 1989; Huffman, W. and R. Evenson, The Development of U.S. Agricultural Research and Education: An Economic Perspective, Chapter 3, draft manuscript, Iowa State University, 1989.

Table 3. Percentage of Research Effort Devoted to Maintenance Research by Commodity

Commodity	Percentage of Research Effort Devoted to Maintenance: Adusei and Norton Estimate*	Huffman and Evenson Estimate**
Corn	34.2	33.0
Wheat	41.5	27.4
Barley	42.2	--
Rice	33.6	--
Oats	35.4	--
Other cereals	--	28.1
Sorghum	40.6	--
Vegetables	41.5	--
Fruits	35.1	--
Fruits and vegetables	--	32.3
Potatoes	39.3	38.7
Tobacco	30.2	29.8
Cotton	39.3	42.4
Hay and forage	33.1	23.2
Soybeans	27.9	35.0
Peanuts	27.6	--
Other oil seeds	--	32.3
Livestock	21.4	--
Poultry	33.4	37.2
Beef cattle	--	30.3
Swine	--	36.0
Sheep and wool	--	43.5
Dairy	--	29.3
All commodities	34.8	--

-- indicates commodities not included in specific studies.

*Adusei, Edward O. and George W. Norton. "The Magnitude of Maintenance Research in the United States." Journal of Production Agriculture, October-December, 1989.

**Huffman, Wallace E. and Robert E. Evenson. The Development of U.S. Agricultural Research and Education: An Economic Perspective. Chapter 3. Draft manuscript, Iowa State University, 1989.

Araji (1989) found a very high percent rate of return to public investment in wheat maintenance research.[28]

VIII. Future Evaluation Needs

The public agricultural research agenda has increasingly included issues related to improving food product and environmental quality, fostering rural development, upgrading the performance of government policies at various levels, and improving the productivity of postharvest activities. Research evaluation efforts are only new beginning to focus on this broader agricultural research agenda.

Methods must be developed to assist research administrators in setting priorities for this broadened agenda of agricultural research. Thus research evaluation and priority setting in the future will need to consider multiple goals and objectives. Cost-effective methods must be designed to generate information for priority setting, including information on environmental externalities associated with or reduced by new technologies. There is a continuing need to assess the costs and benefits of alternative research programs, including their distributional implications. Relationships between public and private research activities and the effects of changing trade policies on research benefits also need increased attention.

To be effective, new priority setting methods will need to be developed in collaboration with administrators in the SAES and USDA. Existing quantitative procedures can be adapted to help research directors make strategic decisions on the relative importance of research on particular commodities and program areas. These decisions will be critical in guiding the future development of human resources (hirings) and in planning future investments in research facilities.

[28]Araji, A.A., "Return to Public Investment in Wheat Research in the Western United States," Canadian Journal of Agricultural Economics 37(1989): 467-479.